LAND, CRYOSPHERE, AND NIGHTTIME ENVIROMENTAL PRODUCTS FROM SUOMI NPP VIIRS: OVERVIEW AND STATUS

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ABSTRACT

The Visible Infrared Imaging Radiometer Suite (VIIRS) instrument was launched in October 2011 as part of the Suomi National Polar-orbiting Partnership (S-NPP: http://npp.gsfc.nasa.gov/). VIIRS was designed to improve upon the capabilities of the operational Advanced Very High Resolution Radiometer (AVHRR) and provide observation continuity with NASA's Earth Observing System's (EOS) Moderate Resolution Imaging Spectroradiometer (MODIS). Since the VIIRS first-light images were received in November 2011, NASA and NOAA funded scientists have been working to evaluate the instrument performance and derived products to meet the needs of the NOAA operational users and the NASA science community. NOAA's focus has been on refining a suite of operational products known as Environmental Data Records (EDRs), which were developed according to project specifications under the former National Polar-orbiting Environmental Satellite System (NPOESS). The NASA S-NPP Science Team has focused on evaluating the EDRs for science use, developing and testing additional products to meet science data needs and providing MODIS data product continuity. This paper will present to-date findings of the NASA Science Team's evaluation of the VIIRS Land and Cryosphere EDRs, specifically Surface Reflectance, Land Surface Temperature, Surface Albedo, Vegetation Indices, Surface Type, Active Fires, Snow Cover, Ice Surface Temperature, and Sea Ice Characterization (http://viirsland.gsfc.nasa.gov/index.html). The paper will also discuss new capabilities being developed at NASA's Land Product Evaluation and Test Element (http://landweb.nascom.nasa.gov/NPP_QA/); including downstream data and products derived from the VIIRS Day/Night Band (DNB).

Index Terms— Remote Sensing, Land Cover, Land Use, Cryosphere, Nighttime Environmental Products

1. SUOMI-NPP PROGRAM OVERVIEW

Starting in 2004, NASA began supporting an S-NPP Science Team for three year study cycles to evaluate the utility of the VIIRS instrument and the associated EDR's for science use. In 2007 and 2011 through another two rounds of funding, investigators were selected to continue to evaluate the EDRs from a science perspective and compare them with science algorithms. Through this time, the NASA VIIRS Land Team developed an open dialog with the NOAA operational product teams in charge of developing, testing and maintaining the JPSS Interface Data Processing Segment's (IDPS) Land algorithms, which has helped with the understanding of the VIIRS Land EDRs and with the incorporation of some improvements within the constraints of the product specifications. Through three major baseline releases in the past 2 years (IDPS Mx6 – Mx8), several improvements have been made; however, a number of improvements suggested by the VIIRS Land Team have yet to be adopted as they are either considered to be of lower priority, beyond the specified requirements, incompatible with the IDPS processing implementation, or too costly [1].

2. VIIRS LAND PRODUCT CATEGORIES

A number of higher order products known as Environmental Data Records (EDRs) are being generated within the Joint Polar Satellite System (JPSS) Common Ground Systems and Operations Project. The VIIRS Land products are grouped into four general product categories: (1) radiation budget variables, i.e. the Surface Reflectance IP (corrected for effects of the atmosphere), Land Surface Temperature (LST), and Surface Albedo;

(2) ecosystem variables, such as Vegetation Indices (VI); (3) land-cover characteristics i.e. Surface Type (ST) and the location of Active Fires; and (4) cryospheric products, i.e., Snow Cover, Ice Surface Temperature (IST) and Sea Ice Characterization. A number of these products, including the surface reflectance have their heritage in the MODIS product algorithms and in some cases early versions of the MODIS code were used by the operational VIIRS EDR algorithm development teams.

3. PRODUCT STATUS TO DATE

The VIIRS LST EDR requires a measurement accuracy of 1.5 K and a measurement precision of 2.5 K. Initial results indicate that the LST EDR is within 0.30 +/- 0.21 K of MODIS; with VIIRS being slightly warmer over water and dense vegetation canopies [2]. A science-quality LST product needs to be offered that includes accurate and physically retrieved temperatures and emissivities over arid and semi-arid regions. This product would then be merged with the IDPS product, which is suitable for areas with dense vegetation cover or areas of water.

Figure 1: Land PEATE- adjusted version of VIIRS Surface Reflectance IP. Spatially gridded VIIRS Surface Reflectance products are now available at both moderate (0.5 – 1.0 km) and CMG resolutions through LAADS (http://laadsweb.nascom.nasa.gov/).

The NDVI variable within the Vegetation Index (VI) EDR is generated from Top-of-Atmosphere measurements and will have very little value to the scientific and applications communities already routinely using NDVI values that are atmospherically corrected. While the enhanced vegetation (EVI), which is also part of the VI EDR, is atmospherically corrected, there are blue-band discrepancies that will impact the continuity with the MODIS EVI and related long term data sets [3]. A top-of-canopy NDVI variable is being added to the VI EDR for the JPSS 1 satellite and the EVI variable is being adjusted.

In its present state, the VIIRS Surface Albedo EDR is currently not suitable for climate applications. A primary difficulty is that the original specification only called for a single broadband value (0.3 – 4.0 µm); whereas most (if not all) numerical prediction models, global climate, and biogeochemical models currently in use call for a representation of the surface radiation in terms of both the photosynthetically active radiation (shortwave radiation less than 0.7µm) and the near and mid-wave radiation (0.7- 4.0 µm) [4].

Since the operational user has no access to the underlying spectral anisotropy models (i.e., the BRDF Intermediate Product or IP) for each location, they are also precluded from computing spectral albedos for themselves, from computing albedo under other illumination conditions, from specifying the surface atmospheric boundary conditions, or from correcting surface reflectances to a common view-angle. Note that reflectances corrected to a nadir view geometry (Nadir BRDF-Adjusted Reflectances or NBAR) are the primary input for the MODIS land cover and phenology products and a number of direct broadcast localities have already implemented the MODIS daily BRDF anisotropy model retrieval algorithm so that they can generate view angle corrected data to monitor local land cover change, assess rangeland capacity, and estimate agricultural productivity [5]. NBAR values are also required by VIIRS to assist in the cloud algorithms.

The Surface Type EDR has good probability of providing continuity with the MODIS land cover product in support of climate science research and applications performed at sufficiently coarse scales (> 1 degree). However, the quality and accuracy of the surface type EDR will not be sufficient to support meaningful land cover change detection. This issue is especially relevant to studies that require local-to-regional land cover change products to quantify dynamics in terrestrial carbon and energy budgets. Part of this issue is related to the 1 km spatial resolution of the IP and EDR, and part is related to limitations of the classification algorithm and the IGBP classification scheme.

The Sea Ice Characterization EDR, in its present form, is not suitable for climate applications, unless the product is used strictly as an "ice vs. no-ice" classifier. With only three classes (Ice free, New/Young, and Other ice), and a relatively low probability of correct classification, its usefulness for scientific research is somewhat limited. The Ice Surface Temperature (IST) algorithm, will meet the science community needs [6]. However, additional tuning is needed to correct for biases in ice surface temperature when compared to the MODIS IST product. The IST EDR should also be enhanced by extension to coastal and land ice areas.

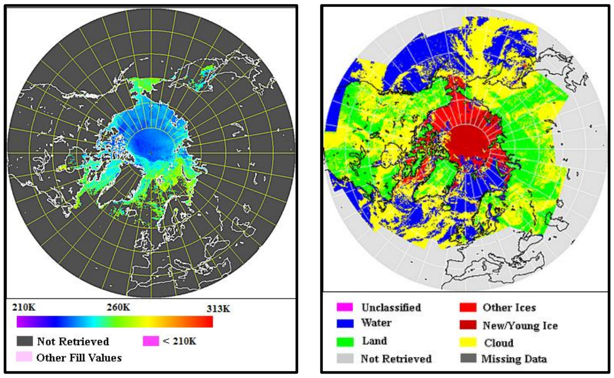

Figure 2: (Left) VIIRS Ice Surface Temperature and (Right) Sea Ice Characterization EDRs for 3/20/12. Reprocessing for IceBridge campaign: Latest code versions (MX6.3) were matched up with early 2012 NASA P3-B airborne campaign data.

The Ice Characterization EDR could be improved for science use by inter-use of data from passive microwave sensors; particularly with respect to ice-age during non-summer periods. The Snow Cover EDR will provide continuity with the MODIS product, but could be enhanced by the inclusion of fractional snow cover and daily snow albedo, as provided by MODIS, and by adopting a multi-sensor approach.

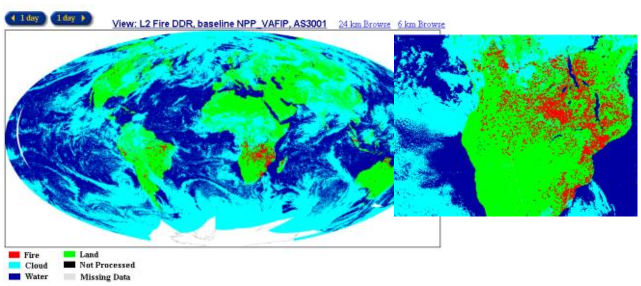

Figure 3: VIIRS Level 2 Active Fires Diagnostic Data Record (NPP_VAFIP). Baselining and integration of this algorithm occurred on 8/12/2012.

The Active Fire Applications Related Product (ARP) as currently produced, lacks the contextual fire mask and fire radiative power data (FRP) layers that have been present in the MODIS active fire product, and are now standard components of most contemporary active-fire data sets [7]. Therefore, a new product that includes the fire mask and the FRP is scheduled to be implemented in the NOAA operational system for the JPSS 1 satellite at the latest [8]. The fire products generated by the IDPS are currently not available in the formats generated by the MODIS data dissemination systems i.e. LANCE FIRMS and Rapid Response, but reformatted data are available through the product evaluation portal at viirsfire.geog.umd.edu. There is an expectation from the NASA applied science user community that real-time fire data dissemination capabilities will be available for VIIRS.

Many of the other land products including vegetation index, surface albedo, and quarterly surface type depend directly on the Surface Reflectance (SR) Intermediate Product (IP) [9]. This product is the direct heritage of the MODIS reflectance product with the associated scientific benefits demonstrated for the downstream MODIS products such as vegetation index, surface albedo, land cover type and LAI/FPAR. At this time, Daily Gridded VIIRS Surface Reflectance is currently not retained by the IDPS or stored in the long-term CLASS archive. This product is required for producing other higher-level (Level 3) land products. The accuracy of the Surface Reflectance IP depends on the aerosol optical thickness IP, which is different from the VIIRS AOT EDR and not readily accessible. This differs from the MODIS processing where the aerosol retrieval is integrated in the same algorithm for the MODIS surface reflectance product. The VIIRS Aerosol Optical Thickness (AOT) IP over land uses similar aerosol models and retrieval techniques similar to those of MODIS. On the other hand, current VIIRS AOT validation analysis shows that it has a substantial high bias over land affecting surface retrievals. The VIIRS SR retrieval accuracies also begin to decline under various surface-atmosphere conditions particularly for the shortwave channels (where the Lambertian assumption introduces biases that depend on the viewing geometry and atmospheric opacity), over bright surfaces, and over regions with variable aerosol sources including dust.

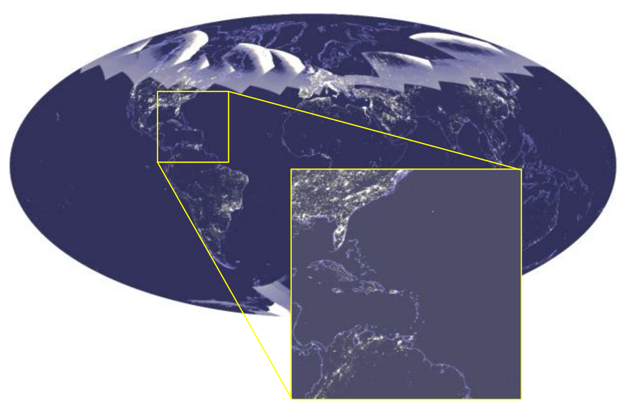

Figure 4: VIIRS Day/Night Band Sensor Data Record (SDR) Global Browse Images are now available through NASA's Land PEATE portal: http://landweb.nascom.nasa.gov/NPP_QA/.

In land research and applications, the VIIRS Day/Night Band (DNB) will advance the study of urbanization dynamics at regional and global scales [10].

The availability of stable, well-calibrated, nighttime radiances is of particular value to improve understanding of urbanization trajectories through the explicit representation of urban land cover, urban population, and urban socio-economic activities [11, 12].

4. VALIDATION EFFORTS

Product validation continues to be an important part of the MODIS Land Team activity, is required for the VIIRS Land EDRs and will be required for the Land Science Products. Recognizing the validation experience-base that resides within the MODIS Team and the global land community, the JPSS project formed an EDR Land Validation Team. Although this team has strong overlap with the NASA MODIS Land Team membership, its scope is limited to the operational specifications, algorithms, and products but benefits heavily from the MODIS validation experience.

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